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Trees for Planting on Strip-Mined Land in Illinois

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(Maintained in cooperation with
Southern Illinois University, Carbondale, Illinois)

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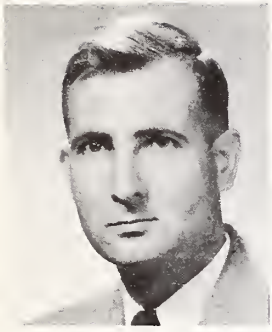
THE AUTHORS



STEPHEN G. BOYCE has been project leader in regeneration and tree improvement research at our Carbondale Center for the past 2 years. Experienced as a teacher as well as a researcher, Steve taught biology and botany at Meredith College, North Carolina State College, and Ohio University before coming to the Station in 1957. His alma mater is North Carolina State where he earned bachelor and master degrees in forestry and a doctorate in plant ecology.

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Trees for Planting on Strip-Mined Land in Illinois

S. G. Boyce and D. J. Neebe

More than 12,000 acres of plantations have been established on strip-mined land in Illinois. Most of the species planted have survived and grown on at least some sites. Other trees have died or made poor growth because the species were not suited to the climate or the site.

After more than 10 years of observing plantations and experimental plantings, we found 17 tree species that are suitable for planting in different areas and on different strip-mined sites. Each species was rated from its survival and rate of growth at least 10 years after planting and from its susceptibility to damage by insects, rodents, and diseases. We found 10 species suitable for planting in all strip-mining counties and 7 additional species suitable for the southern counties. Species for the southern area were either not hardy or were not observed in the northern counties.

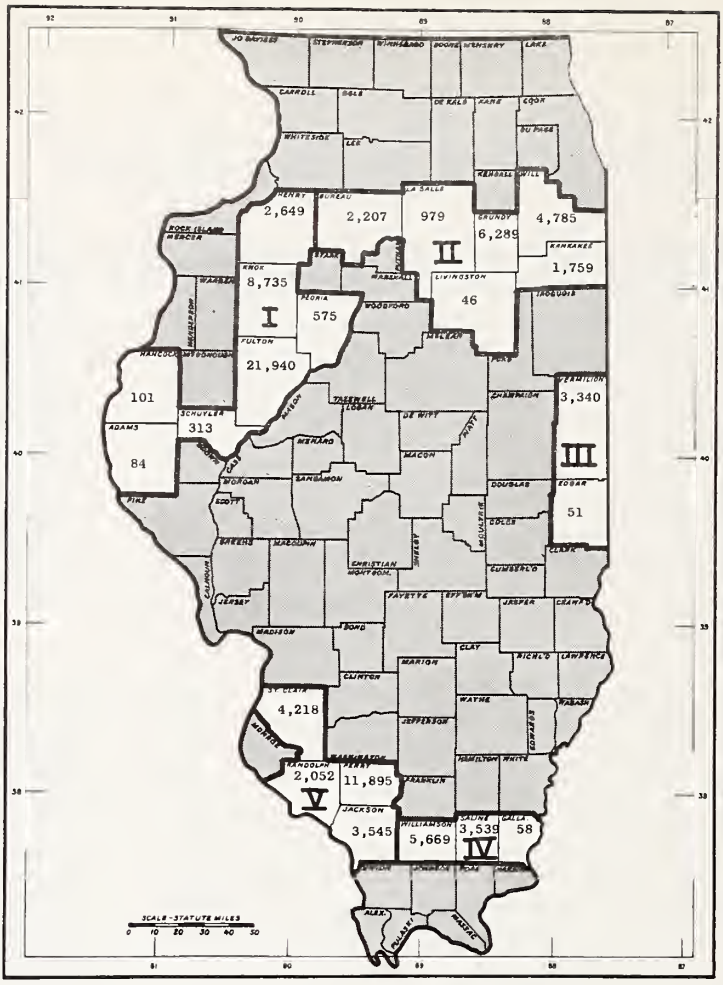

Figure 1.--The five strip-mining districts and the acreage affected in each county to January 1, 1958.

THE TEST AREAS

The strip-mined land was divided into five districts (fig. 1). Each district represents different combinations of spoil-bank conditions that affect tree growth and survival. Their conditions were previously described in detail (9). Experimental plantings were made on representative areas in each of these districts.

District I

Nearly all the overburden in these counties was composed of thick, fertile mantles of loess, glacial till, and calcareous shale. The resulting mixture was usually friable, calcareous, and well drained. There was more loess in Knox and Fulton Counties and more till in Henry County. This was some of the most productive strip-mined land in the State.

This district was represented by plots on calcareous, silty clay banks in Fulton County. The area had been strip mined less than 1 year and no vegetation was present at the time of planting. The banks ranged in height from 1 to 15 feet, slopes were steep, and there was some sheet and gully erosion. The pH of the surface material ranged from 7.7 to 8.3. Due to the high clay content some depressions were poorly drained and standing water was common following rains (fig. 2).

Figure 2.--Many trees drowned in the poorly drained depressions of this otherwise highly productive area in Fulton County.

District II

Most of the strip-mined land in these counties differed greatly from that found elsewhere in the State. The overburden was primarily of glacial origin and was composed of calcareous sand and small amounts of calcareous shale, limestone, and sandstone. In Bureau and La Salle Counties some of the banks were calcareous shaly loams and clays, while in Will and Grundy Counties banks were usually calcareous sands or sandy clays and clay loams. Small toxic and acid spots occurred, mostly in La Salle County where coal was stripped in conjunction with clay mining.

Two adjacent plots were planted in Grundy County. The area was strip mined about 1 year before planting and natural vegetation was sparse and scattered. The surface material was fine, gray-brown, calcareous sand with small amounts of shale and clay. The pH ranged from 7.7 to 8.3. The banks ranged in height from 6 to 25 feet, slopes were steep, and there was moderate sheet and gully erosion.

District III

Most of the overburden in these counties consisted of sand and clay of glacial origin and a gray, calcareous shale. A few scattered areas were toxic or acid, but in general the material left after stripping was calcareous. This type of overburden extended into Vermillion and Vigo Counties, Indiana (4).

The plantings studied for this District were located near the Illinois-Indiana state line in Vermillion County, Indiana. They were on well drained, glacial till (fig. 3) representative of

Figure 3.--The banks in district III were composed of well-drained, glacial till. Most experimental areas had ridge-and-valley topography.

the Vermilion-Edgar County region of Illinois. The surface material was a mixture of sand, clay and calcareous shale. Two plots were planted with mattocks and two were planted with planting bars. A third set of plots was planted on older banks with a sparse cover of natural vegetation. All pH values were greater than 7.0.

District IV

In this district the material left after strip mining was composed chiefly of loessal silt, glacial till, shale, and some limestone and sandstone. Many of the banks were calcareous, but on others pH ranged from 3.0 to 8.0 within distances of 2 to 3 feet. On these areas where acid and basic material were mixed, acidity was continually changing.

In Saline County two plots were located on an ungraded area where relief ranged from 10 to 50 feet. There was moderate sheet and gully erosion. Natural vegetation consisted of a few cottonwoods, sycamores, boxelders, and scattered herbaceous plants. At the time of planting, pH for 10 randomly selected soil samples ranged from 2.7 to 6.3 and 9 of these samples had pH values of 4.0 or less.

Nearby, two plots were located on a roughly graded area. This area was leveled with a dragline that left a gently undulating surface with a range in relief of 1 to 4 feet (fig. 4). Ten randomly selected soil samples had a pH ranging from 4.9 to 7.2 with 6 of the values greater than 6.4. Here grading apparently covered some of the acid material. This area was difficult because of large rocks, 1 to 2 feet in diameter. Natural vegetation consisted of a few cottonwoods and scattered herbaceous plants.

Figure 4.--This area in Saline County was graded with a dragline before planting.

District V

The strip-mined land of this district generally consisted of calcareous shaly loams and clays. A few areas had acid, silty clays some of which were toxic. In Perry, Jackson, and Randolph Counties large limestone boulders were commonly scattered over the surface of the banks. In St. Clair County the surface material had a high content of loess and was highly productive.

Very acid and toxic conditions were represented by two plots in Jackson County. The pH of 10 random soil samples ranged from 2.3 to 6.8 and six of the samples had a pH less than 4.0. The surface material was a mixture of dark, acid shale, loess, and gray, silty clay. Twenty percent of the surface was toxic.

In contrast to these plots, two calcareous areas were planted in Randolph County. More than 60 percent of these plots had a pH greater than 7.0. One bank was 3 years old and had a dense cover of sweet clover while the other was 1 year old and practically bare at the time of planting. The surface material on both areas consisted of loess, glacial till, and silty clay.

THE PLANTINGS

In 1947 seventeen species of trees were planted on each of the plots in these counties. The rows, each containing 50 trees, were planted across the contours so differences in survival and growth could be related to site conditions. Plots were replicated two or more times in each area. The following species were planted:

Hardwoods

1-0[1]	Black locust (*Robinia pseudoacacia* L.)[2]
1-0	Black walnut (*Juglans nigra* L.)
	Black walnut seed (*J. nigra* L.)
1-0	Cottonwood (*Populus deltoides* Bartr.)
1-0	Green and white ash (*Fraxinus pennsylvanica* Marsh. & *F. americana* L.)[3]
1-0	Osage-orange (*Maclura pomifera* Raf. (Schneid.))
1-0	Sweetgum (*Liquidambar styraciflua* L.)
1-0	Silver maple (*Acer saccharinum* L.)
1-0	Yellow-poplar (*Liriodendron tulipifera* L.)

Conifers

1-0	Eastern redcedar (*Juniperus virginiana* L.)
2-0	Jack pine (*Pinus banksiana* Lamb.)
1-0	Loblolly pine (*P. taeda* L.)
2-0	Pitch pine (*P. rigida* Mill.)
2-1	Red pine (*P. resinosa* Ait.)
1-0	Shortleaf pine (*P. echinata* Mill.)
1-0	Virginia pine (*P. virginiana* Mill.)
2-1	White pine (*P. strobus* L.)

1/ The dual numbers preceding the names of species refer to the age class of nursery stock used in the planting. For example, 1-0 Virginia pine means that the stock was grown 1 year in the seedbed and not transplanted; 2-1 white pine means that the trees were grown for 2 years in the seedbed and 1 year in the transplant bed at the nursery.

2/ Names from Agriculture Handbook No. 41, Check List of Native and Naturalized Trees of the United States. 1953

3/ Green and white ash seedlings were mixed.

SPECIES FOR PLANTING IN ALL DISTRICTS

Black locust, eastern cottonwood, green and white ash, silver maple, black walnut, Osage-orange, eastern redcedar, jack pine, and red pine were found suitable for planting in all strip-mined areas. However, growth and survival of some species varied by districts. Ash, silver maple, black walnut, Osage-orange, red pine, and jack pine made the best growth in districts I and II. And, in district III ash and silver maple grew better than in districts IV and V. Eastern redcedar made the best growth in districts IV and V while cottonwood and black locust grew equally well in all districts (tables 1-6).[4/]

Black Locust

Black locust was the best species for obtaining a quick plant cover. Because of its high survival, fast early growth and ability to spread by root sprouts, black locust rapidly covered bare areas. Also, nitrogen-fixing bacteria on the roots added nitrogen to the soil, which was in short supply on newly mined areas (5, 7). The addition of nitrogen, organic matter, and shade resulted in other plants and animals invading the areas. Under 20-year-old stands soil horizons and soil structure had begun to form (fig. 5). These features made black locust a good pioneer species for planting newly mined land.

Survival of black locust was better than 70 percent except on very acid and densely vegetated areas. On acid spots less than 20 percent of the black locust survived; however, on very acid areas, locust had the highest survival of any species tested (table 5).

Height of black locust ranged from 9 to 34 feet and varied with acidity and topographic conditions. On the very acid plots of Jackson County median height was only 18 feet but was 24 feet or more on areas with higher pH values. On lower slopes the trees were taller than on ridges.

Black locust was a good "nurse" tree for other hardwoods (2, 3). Because of its fast early growth (4 feet in 2 years) locust gave the best protection when it made up 25 percent or less of the mixed plantings. Our observations indicated all the hardwoods except cottonwood and sycamore were suitable for interplanting with locust. At higher percentages the locust crowded out the other species. None of the conifers were suitable for interplanting.

4/ Tables appear in Appendix, p. 27.

Figure 5.--Organic matter and the surface layer of spoil material under a 21-year-old stand of black locust. The upper 5 inches of spoil material has a well-developed granular structure and many earthworm and root channels.

Black locust had one major fault - it was severely damaged by the locust borer (Cyllene robiniae). All plantings of this study were damaged. Where this insect was abundant there was very little salable material. However, insect-damaged plantations were successfully underplanted with yellow-poplar, black walnut, silver maple, and Osage-orange.

In 1947, seven hardwood species and redcedar were planted under an insect-damaged black locust stand in Perry County. The black locust was 9 years old at the time of underplanting.

After 12 growing seasons yellow-poplar, black walnut, silver maple, and Osage-orange made the best growth (table 7). More than half of the black walnut and yellow-poplar were more than 30 feet tall, which was more than twice the average height of these species where planted in the open. This increased growth was apparently due to increased nitrogen made available by the locust (5) and to the continued heavy thinning of the black locust overstory by borer attacks. However, in recent years borer attacks have decreased and sprouts of the black locust have again formed a closed canopy. Most of the yellow-poplar, black walnut, silver maple, and Osage-orange formed a part of this canopy while most of the sweetgum and ash were overtopped. Apparently growth of the ash and sweetgum in recent years has not been fast enough to keep up with the black locust sprouts. Unless the black locust is again heavily thinned by the locust borer, most of the sweetgum and ash will be eliminated from the stand. The slow growth of the sweetgum may have been caused by rodents which partly girdled some of the trees soon after planting.

Cottonwood and redcedar were complete failures under the locust. Intolerance to shade and poor planting stock were major causes of cottonwood failure. The slower growing redcedar was overtopped by adjacent trees and eventually died although some of the trees survived for 10 years.

In attempting to convert decadent black locust stands to other species the growth rate of the underplanted species, development of ground cover, and the time and degree of deterioration of the black locust canopy must be taken into account. Some underplanting studies have been virtual failures because the planting was delayed until a dense ground cover developed under the opened locust canopy. Other underplanting studies have failed because planting was delayed until borer attacks decreased and locust sprouts formed a dense canopy over the plantings.

To take full advantage of the beneficial effects of black locust, underplantings should be made at the beginning of heavy locust borer attacks. At this time the ground cover is usually sparse, and the seedlings can take advantage of the maximum period of nearly full sunlight.

Black locust has been the most commonly planted tree on strip-mined land of Illinois - more than 2.5 million trees.

Cottonwood

Cottonwood was the fastest growing tree. On calcareous areas many trees were more than 30 feet tall and average heights were more than 20 feet. On lower slopes and alluvial bottoms trees were 30 to 39 feet in height, had straight stems, good form, and a few large branches.

Cottonwood was established both naturally and by planting on spoils of all districts (fig. 6). The growth of natural cottonwood was as good as or better than the planted trees. In some plots the planted trees could not be recognized and measured because of the many natural cottonwoods. In Perry County a 30-year-old natural stand averaged 74 feet in height on the ridges and 82 feet in the valleys. In another natural stand, 15-year-old cottonwood averaged 37 feet in height on the ridges and 54 feet in the valleys. For strip-mined areas in districts IV and V the average site index at age 25 was 78 (11).

On acid areas cottonwood made slow growth or died (table 5). Best growth was made where pH was greater than 6.5.

Figure 6.--On many bare spoils cottonwood becomes established naturally. The trees of this 30-year-old natural stand are 70 to 90 feet in height.

The cottonwood twig borer (Gypsonoma haimbachiana) was observed on some young trees (10). This insect distorts the terminal shoot and frequently causes crooked stems. No disease or rodent damage was noted.

More than 800,000 cottonwood seedlings have been planted on Illinois strip-mined land.

Ash

Green and white ash were best for planting on lower slopes and bottoms, on areas with a pH greater than 5.5, and for planting with sweet clover or other low plants. Both green and white ash were planted on all plots, and there was no apparent difference in the growth and survival between the two species.

These species had better than 68 percent survival on all plantings except the very acid plot of Jackson County. On the densely vegetated area of Randolph County ash had the highest survival of the species tested (table 6). Observations on many areas showed that these relatively tolerant species could be planted where sweet clover or other low plants have formed dense stands.

On lower slopes and bottoms ash made better growth than on ridges. On bottoms many stems were single, straight, and of good form, but on ridges and upper slopes most of the ash had multiple stems. Poor form was a major fault of ash. No disease or insect damage was noted but a few trees in Fulton County were girdled by rodents. Almost 1 million ash have been planted on strip-mined land in Illinois.

Figure 7.--More than half the silver maple had multiple stems in pure plantings. In mixture with other species more of the trees had single stems.

Silver Maple

Silver maple was suitable for planting in mixture with other hardwoods and for underplanting in decadent black locust stands. This species had the highest survival and made the best growth in northern Illinois. Survival was better than 59 percent on the northern spoils but less than 43 percent on the southern areas. Growth was best on the calcareous sands of district II where half of the trees were taller than 25 feet (table 2). On the silt and clay spoils of the other districts average height was 16 feet or less. On all districts the best growth was made in valleys and on lower slopes.

On all topographic positions and on all districts more than half the silver maple had multiple stems and usually several sprouts near the base of the stem (fig. 7). This was the most serious fault of this species. However, in dense stands, the form may have been better. Some trees were damaged by tent caterpillars and a few were partially girdled by rodents.

More than 800,000 silver maples have been planted on strip-mined land in Illinois.

Black Walnut

Black walnut was well suited for planting in mixture with other hardwoods and for underplanting in decadent black locust stands. It was not suitable for planting in pure stands or on acid areas (pH less than 6.5). On calcareous areas more than half the walnut trees were taller than 8 feet while on acid areas most trees were less than 4 feet tall. In pure stands the crowns were flat topped and the stems had poor form.

Both seedlings and seed were used to establish black walnut on spoils. Seedlings from seed made as good or better growth than planted seedlings. Walnut from seed and seedlings grew slowly during the first 5 years, but between the 7th and 10th years most of the trees averaged 1 to 2 feet of height growth per year. In mixed plantings more than 60 percent of the stems were single, straight, and had good crowns.

More than 900,000 black walnut seeds and seedlings have been planted on strip-mined land in Illinois.

Osage-Orange

Osage-orange was suitable for planting in dense stands on upper slopes and ridges and for underplanting in decadent black locust stands. It grew best where pH was greater than 4.5 and on well-drained areas.

Osage-orange had 33 to 67 percent survival and made the best growth in districts III, IV, and V. In Northern Illinois and on acid areas (pH less than 4.5) survival was less than 27 percent. In single row plantings this species had very poor form. When grown in dense stands the form should be better and the trees should produce very durable fence posts.

Approximately 99,000 Osage-oranges have been planted on strip-mined land.

Eastern Redcedar

Redcedar is an evergreen that can be planted for Christmas trees, wildlife cover, windbreaks aesthetic plantings, and wood products (fig. 8). Mourning dove nests were found in many trees and other bird nests were common. The tops of more than 30 percent of the redcedar had been cut for Christmas trees and many

Figure 8.--These 10-year-old redcedars average 11 feet in height. On calcareous areas this species can be grown for Christmas trees.

large trees had been cut near the ground. After the tops were removed two to three side branches became dominant and some of these were later taken for Christmas trees. Survival of redcedar on calcareous areas was nearly 50 percent except in Grundy County where only one tree survived. On the acid plots of Jackson County survival was only 8 percent.

In southern Illinois and on the Indiana plots most trees were 9 to 12 feet tall but averaged only 6 feet in Fulton County. The best growth was made on calcareous upper and lower slopes and the slowest growth was made on very acid areas and on poorly drained bottoms.

Damage by bagworms occurred on one planting in Indiana. In extensive plantings, damage by this common pest of redcedar may be more serious. Fruiting bodies of apple rust were observed on one planting in Randolph County. No rodent damage was found.

Approximately 133,000 redcedars have been planted on strip-mined land in Illinois.

Jack Pine

Jack pine was well adapted for planting on all sites except poorly drained bottoms and areas subject to flooding. This species was successfully planted on acid and calcareous areas and on clay and sandy areas. On the very acid plots of Jackson County survival was 30 percent and half the trees were more than 10 feet tall. On the calcareous areas of northern Illinois survival was greater than 40 percent and half of the trees were taller than 9 feet. However the best survival and growth occurred where pH was near 6.5. On slopes and ridges growth was better than in poorly drained valleys but in very rocky or sandy valleys growth was better than on the ridges. On south and west slopes jack pine growth was better than that of the hardwoods. No serious disease, insect, or rodent damage was observed.

More than 600,000 jack pines have been planted on strip-mined land in Illinois.

Red Pine

This species was selected for planting on upper slopes, ridges, and well-drained bottoms where the pH was greater than 5.6. It was better suited for districts I and II than for southern Illinois. No serious insect, disease, or rodent damage was observed. More than 400,000 red pines have been planted on Illinois strip-mined land.

Figure 9.--The trees in this 10-year-old plantation of sweetgum in district IV average 15 feet in height. Most of the trees have single, straight stems.

ADDITIONAL SPECIES FOR THE SOUTHERN DISTRICTS

Sweetgum, yellow-poplar, loblolly pine, shortleaf pine, and Virginia pine were suitable species for planting only in southern Illinois. These trees were not hardy in the northern counties. Plantings of northern red oak and sycamore were observed only in the southern counties.

Sweetgum

This species had the best growth form of all the hardwoods (fig. 9). More than 75 percent of the trees had single, straight stems and conical crowns. In southern Illinois survival was better than 50 percent except in dense vegetation and on very acid areas. Half of the trees were more than 10 feet tall on all kinds of topography, and many were 20 to 25 feet tall on silty clay bottoms. No diseases were observed but a few trees had bagworms that caused some defoliation. The most serious pests were rodents which clipped the tops of young trees and partly girdled some trees up to 3 inches in diameter.

Sweetgum made the best growth on lower slopes and bottoms where pH was more than 5.5. It was suitable for planting on areas with periods of flooding up to 1 week, for pure plantings, and for use in mixed plantings with silver maple and ash. It was not suitable for planting in the northern counties where survival was less than 20 percent and many trees were damaged by ice.

More than 129,000 sweetgum have been planted on strip-mined land in Illinois.

Figure 10.--Trees in this 10-year-old yellow-poplar plantation range from 1 to 8 feet in height. The 10-year-old cottonwood in the background averaged 40 feet in height.

Yellow-Poplar

Yellow-poplar was one of the best species for underplanting decadent black locust stands. In several underplanting studies it was consistently the fastest growing species (table 7). In Perry County half the yellow-poplar were taller than 30 feet 12 years after underplanting. In Saline County most of the yellow-poplar were more than 6 feet tall 5 years after planting under a locust-borer-infested stand. Survival has been more than 30 percent.

However, yellow-poplar was not suitable for planting in pure stands on bare areas. Under these conditions survival ranged from complete failure to 37 percent and average heights were less than 11 feet. In these plantings, the heights among trees were extremely variable (fig. 10). Many trees died back to the ground several times and rodent damage was common on all areas. A stem canker, tentatively identified as yellow-poplar dieback (12), occurred in some pure plantings. There was no opportunity to observe underplanted yellow-poplar in the northern counties.

About 290,000 yellow-poplar have been planted on Illinois strip-mined land.

Sycamore

Sycamore was one of the best hardwoods for planting in the southern strip-mined area where pH ranged from 4.5 to 8.0. It was suitable for planting silty-clay areas and for bottoms where periods of flooding do not exceed 1 week. Sycamore can also be planted where sweet clover or other low plants form a sparse cover.

Figure 11.--More than half of the trees in this 10-year-old sycamore plantation were taller than 25 feet and survival was better than 70 percent.

However, it should not be underplanted in black locust stands. The stems were straight and had good form but branches were persistent (fig. 11). Sycamore was subject to attack by anthracnose (Gnomonia veneta) which resulted in deformed stems. There was no opportunity to observe planted sycamore in the northern counties. Approximately 235,000 sycamores have been planted.

Northern Red Oak

Northern red oak was one of the best hardwoods for planting on well-drained lower slopes and in mixture with ash, maple, black locust and walnut. It had better than 50 percent survival except on very acid or flooded areas (fig. 12). Height growth averaged 8 to 12 feet in 10 years in Perry and Saline Counties. However, the young oak seedlings were clipped by rabbits, reducing the height growth for several years after planting. No insect or disease damage was observed. There was no opportunity to observe planted oaks in the northern counties. More than 280,000 oaks have been planted.

Figure 12.--This 18-year-old plantation of northern red oak averaged 30 feet in height and survival was more than 50 percent.

Loblolly Pine

Loblolly pine was the fastest growing pine planted on acid (pH 4.5 to 6.9) strip-mined areas of southern Illinois (tables 4 and 5). Many trees averaged 2.5 feet of height growth per year. Best growth was on well-drained bottoms and lower slopes, but heights of 10 feet in 10 years were made on ridges. This species was suitable for planting in sparse stands of sweet clover. It was not suitable for underplanting or mixed planting. In northern Illinois all loblolly pines were killed by freezing. More than 900,000 loblolly pines have been planted on strip-mined land in Illinois.

Shortleaf Pine

Shortleaf pine was the best pine for planting strip-mined land in southern Illinois. Growth and survival were almost as good as for loblolly pine, but shortleaf was more resistant to breakage during ice storms. The best growth was made on acid slopes (pH 4.5 to 6.9). Shortleaf pine was, however, heavily infested with tipmoth and many branch tips were killed back year after year. In northern Illinois all shortleaf pines were killed by freezing.

Shortleaf pine plantations can be underplanted with hardwoods. Growth of underplanted hardwoods was not as fast as when planted under locust, but growth and survival of yellow-poplar and black walnut were better under the shortleaf pine than in open areas. Eight species were planted under an 8-year-old shortleaf pine plantation 1 year after the pine was damaged by freezing. The pine recovered and there was no evidence of freezing injury 12 years later. However, the underplanted yellow-poplar, black walnut, black locust, Osage-orange, and sweetgum were dominants (table 7). More than 2 million shortleaf pines have been planted on strip-mined land in Illinois.

Virginia Pine

Virginia pine was an excellent tree for wildlife cover. It had straight but very tapered stems. Branches persisted and, on most trees, extended to the ground. Because of these characteristics, this species was better suited for wildlife cover than for wood products.

Virginia pine was hardy in the northern counties but survival was much less than for jack, pitch, and red pine. The best growth was made in Saline County where half of the trees were taller than 10 feet. The highest survival was on slopes, ridges, and on acid areas (pH 4.5 to 6.9). About 200,000 Virginia pines have been planted on strip-mined land in Illinois.

SPECIES FOR VARIOUS SITE CONDITIONS

Survival and growth of trees planted on strip-mined land were affected by differences in topography, aspect, erosion, soil reaction, ground cover, and grading.

Topography and Aspect

As a general rule, conifers were better suited for planting on ridges and upper slopes; hardwoods were better suited for planting on lower slopes and in valleys. Valleys that were flooded for periods of less than 1 week were best planted to cottonwood, sycamore, ash, silver maple, and sweetgum. None of the pines tested were tolerant to flooding.

On north- and east-facing slopes black walnut, cottonwood, green and white ash, sweetgum, and silver maple were most suitable. The pines, redcedar, Osage-orange, and black locust were suitable for planting on south- and west-facing slopes.

Erosion

Planting trees on highly erosive slopes was not successful. Most planted trees were washed from the slopes and others were buried in the bottoms. On these areas it would have been best to have delayed planting until erosion and slumping had produced moderate slopes and alluvial deposits in the valleys (fig. 13). Trees planted on these eroded slopes and alluvial deposits would have had better survival and growth than trees planted on the original erosive slopes and V-shaped valleys. Of all the species planted on erosive slopes, black locust did best.

Figure 13.--On highly erosive areas it is best to delay planting until erosion and slumping have formed moderate slopes. The black locust planted on this highly erosive area made the best growth of all the species tested.

Figure 14.--The bare spots on this Jackson County area have a pH less than 4.0 and are toxic. Trees planted on the toxic spots died. Pines had better survival and growth near the toxic spots than the hardwoods.

Soil Reaction

As a general rule, the pines were better suited for planting on acid areas and the hardwoods were better suited for calcareous areas. However, the best growth of all species was made where the pH was near 6.5. For more acid areas (pH 4.5 to 5.5) the pines, black locust and sweetgum made better growth. For more calcareous areas (more than pH 7) the hardwoods, redcedar, and red pine made the best growth. Cottonwood and black walnut were only suited to areas with pH greater than 6.5.

Where more than half of the material had a pH less than 4.0, the area was too toxic for most plants (fig. 14). On these areas it would have been best to delay planting until weathering and leaching removed the toxic materials. Fortunately, only about 1 percent of the strip-mined land of Illinois is too toxic for immediate planting (8).

Results from the Jackson County plots show the low survival and slow growth to be expected on very acid areas. Survival for most species was less than 30 percent and most trees were less than 10 feet tall. Survival and growth of the best species--black locust, loblolly pine, and jack pine--was less than the average for these species on other areas.

Toxic conditions lasted for 10 years. At the time of planting, 20 percent of the plots were too toxic for plant growth and 60 percent of the area had a pH less than 4.0. At the end of 10 years the absence of natural vegetation indicated the areas were still toxic. Cottonwood, sweet clover, horse-nettle, goldenrod,

and ragweed, which naturally become established on less acid areas (1) were absent. Some trees were killed 5 to 10 years after planting when their roots extended into pockets of toxic material. This was in contrast to nontoxic areas where mortality was usually highest during the first 2 years.

Ground Cover

Where dense stands of sweet clover and other plants developed before planting, most planted tree seedlings died. However, some species--ash, redcedar, black walnut, black locust, Virginia pine, loblolly pine, and Osage-orange--were successfully planted in dense natural vegetation. On the densely vegetated plots of Randolph County survival of all species was less than on the sparsely vegetated plots. However, on the densely vegetated site ash and redcedar had the best survival, 71 and 52 percent respectively. Black locust, black walnut, Osage-orange, Virginia pine, and loblolly pine had 29 to 34 percent survival; none of the yellow-poplar or cottonwood survived (table 6).

The dense stand of sweet clover did not affect height growth as much as it did early survival. Between the heavily vegetated and sparsely vegetated areas there was little difference in growth of the surviving trees.

Sparse and scattered vegetation helped survival of planted trees (fig. 15) by lowering surface temperatures during the summer and increasing organic matter. On the sparsely vegetated areas, black locust and ash had 83 percent survival. Sweetgum, black walnut, Osage-orange, pitch pine, and redcedar had 60 to 70 percent survival. Cottonwood had become naturally established throughout these plots and it was difficult to separate the planted from the natural trees.

Figure 15.--This 2-year-old sycamore was planted in a sparse stand of sweet clover. The clover is now dense, but the sycamore is well established and can be expected to make good growth.

Graded Areas

On graded areas slight depressions caused by unequal settling filled with water and drowned planted trees. Also, the compaction of surface soil, particularly areas of high clay content, reduced the survival and growth of trees for at least 10 years (6, 7). On these areas species tolerant to short periods of flooding, such as sweetgum, silver maple, ash, and cottonwood, were most suitable.

Grading may also change the soil reaction of the surface material and thus affect tree growth. On the Saline County plots grading with a dragline covered some of the acid material and exposed calcareous material. Differences in survival and growth between the graded and ungraded sites were due to differences in acidity and to compaction and surface drainage. On the ungraded area, 9 of the 10 soil samples had a pH of 4.0 or less. Species that normally perform best on acid soil--silver maple, sweetgum, jack pine, red pine, loblolly pine, Virginia pine, white pine, and shortleaf pine--had 23 to 95 percent higher survival on the ungraded than on the graded area. All of these species except silver maple were slightly taller on the ungraded than on the graded area. On the graded area, where more than half of the soil samples had a pH greater than 6.4, 64 to 120 percent more walnut and cottonwood survived than on the ungraded areas. These species normally have better growth and survival where the soil pH is greater than 6.5. Species that can be planted on both acid and calcareous areas--black locust, redcedar, pitch pine, and ash--had differences in survival of less than 14 percent between the graded and ungraded areas (table 4).

Because graded areas differed greatly in soil reaction, degree of compaction, and drainage, it was not possible to select the most suitable species for graded areas. Species for planting on these areas must be selected according to acidity, water drainage, compaction, and texture of the surface material.

Grading some ridgetops to produce access roads or to cover toxic materials had good results. However, grading entire areas before planting with forest trees does not seem to be desirable (6).

SPECIES NOT SUITABLE FOR PLANTING

Because of the poor growth of white pine and the poor form of pitch pine, these species should not be used in forest plantings.

White Pine

In northern Illinois and on the Indiana plots 22 to 54 percent of the white pine survived but half the trees were less than 4 feet in height. Many of the trees in these districts were less than 2 feet tall and had bushy, globe-shaped crowns. It is doubtful whether they will ever attain merchantable size.

On the southern areas survival and height growth were best on the acid ungraded area of Saline County; but, even here, white pine had the lowest survival and made the slowest growth of the conifers. Survival on the other southern plots was not much better than in northern Illinois. In some plantings a few individuals made better than average growth. No serious disease, insect or rodent damage was observed on white pine.

About 278,000 white pines have been planted on strip-mined areas in Illinois.

Pitch Pine

Pitch pine was successfully planted on all sites except poorly drained areas. However, pitch pine was very crooked, limby, and had poor form. Because of this it was the least desirable of the pines. Tip moth damage was common in all plantings and in Grundy County most of the pitch pine was severely damaged by ice storms.

About 157,000 pitch pines have been planted on strip-mined land in Illinois.

SUMMARY

Seventeen species of trees were found suitable for planting on strip-mined land in Illinois. Ten species were suitable for planting in all parts of the state; seven additional species were suitable for the southern counties. The best survival and growth was obtained where species were carefully selected for the various sites and only the best quality stock was planted. The species selected and their suitabilities are summarized as follows.

For all districts:

Black locust	For obtaining a quick plant cover. Can be planted on all sites. Makes the best growth on well-drained lower slopes of moderate acidity. Attacked by locust borer. Equal growth rate in all districts.
Cottonwood	For fast growth. Must be planted in pure stands on bare areas. Best growth was on calcareous lower slopes and bottoms. Equal growth rate in all districts.
Green and white ash	For frequently flooded lower slopes and bottoms, and in stands of sweet clover or other low plants. Also for use in hardwood mixtures. Best growth was on lower slopes in districts I and II where pH was above 5.5.
Silver maple	For well-drained bottoms and lower slopes of calcareous areas, for underplanting black locust, and for hardwood mixtures. Best growth was in districts I and II.
Black walnut	For underplanting black locust and for mixed plantings. Not for pure plantings. Best growth was in districts I and II and on well-drained calcareous areas with black locust.
Osage-orange	For dense plantings on upper slopes and ridges and for the drier sites in black locust stands. Best growth was in districts I and II and on areas with pH greater than 4.5.

Eastern redcedar	An evergreen for windbreaks, Christmas trees, wildlife cover, and wood products. Best growth was in districts III, IV, and V and on well-drained bottoms. Pure plantings only.
Jack pine	A pine for planting on all sites except poorly drained bottoms and areas subject to flooding. Best growth was in districts I and II and on areas with a pH near 6.5. For pure plantings only.
Red pine	For upper slopes, ridges and well-drained bottoms where pH is more than 5.6. Best growth was in the northern counties. Pure plantings only.

Additional Species for the southern districts:

Sweetgum	For lower slopes and bottoms. Had the straightest stem and the best form of all the hardwoods. For pure plantings or mixed with other hardwoods.
Sycamore	For planting where pH ranges from 4.5 to 8.0 and where sweet clover forms a sparse cover. For all slope positions, for pure plantings, and for mixed plantings with other hardwoods.
Northern red oak	For planting on slopes and well-drained bottoms in mixture with other hardwoods.
Yellow-poplar	For underplanting decadent black locust stands. Not for pure plantings.
Loblolly pine	For fast growth on acid (pH 4.5 to 6.9) areas. Must be planted in pure stands. May be damaged by ice storms.
Shortleaf pine	The best pine for planting on strip-mined land in southern Illinois. Best growth on well-drained areas with pH from 4.5 to 6.5.
Virginia Pine	For wildlife cover on acid areas (pH 4.5 to 6.5).

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APPENDIX

Table 1.--Ten-year survival and median heights of trees planted in Fulton County (District I)

Species	Survival	Median height
	Percent	Feet
Black locust	81	27
Ash	92	14
Silver maple	74	16
Cottonwood	53	23
Sweetgum	19	10
Black walnut	18	11
Black walnut seed	1/ 45	10
Osage-orange	27	12
Yellow-poplar	31	11
Jack pine	89	12
Pitch pine	48	8
Red pine	72	5
Virginia pine	36	10
White pine	54	4
Shortleaf pine	0	--
Loblolly pine	0	--
Eastern redcedar	58	6

1/ Percent of seed spots with one or two live trees.

Table 2.--Ten-year survival and median heights of trees planted in Grundy County (District II)

Species	Survival	Median height
	Percent	Feet
Black locust	71	28
Ash	82	18
Silver maple	75	25
Cottonwood	62	29
Sweetgum	3	15
Black walnut	5	6
Black walnut seed	1/ 13	13
Osage-orange	24	17
Yellow-poplar	0	--
Jack pine	41	9
Pitch pine	30	5
Red pine	38	6
Virginia pine	7	11
White pine	22	2
Shortleaf pine	0	--
Loblolly pine	0	--
Eastern redcedar	1	2

1/ Percent of seed spots with one or two live trees.

Table 3.--Ten-year survival and median heights of trees planted in Vermillion County, Indiana (District III)

Species	Site I (Mattock-planted)		Site II (Bar-planted)		Site III (Sparse vegetation)	
	Survival	Median height	Survival	Median height	Survival	Median height
	Percent	Feet	Percent	Feet	Percent	Feet
Black locust	89	26	98	26	95	27
Ash	68	12	92	12	83	14
Silver maple	67	14	59	11	60	9
Cottonwood	1/ --	--	1/ --	--	1/ --	--
Sweetgum	41	10	21	9	67	10
Black walnut	28	7	40	7	56	6
Black walnut seed	2/ 74	9	2/ 52	8	2/ 69	8
Osage-orange	48	11	46	11	67	11
Yellow-poplar	11	8	7	6	28	8
Jack pine	74	12	65	9	52	9
Pitch pine	58	7	41	4	41	7
Red pine	37	4	34	3	32	4
Virginia pine	41	9	27	8	24	8
White pine	38	3	24	2	29	2
Shortleaf pine	5	6	2	3	2	3
Loblolly pine	7	5	2	8	8	10
Eastern redcedar	73	9	49	10	61	10

1/ Survival and height measurements were not taken because of the difficulty of separating planted cottonwood from the natural cottonwood.

2/ Percent of seed spots with one or two live trees.

Table 4.--Ten-year survival and median heights of trees planted in Saline County (District IV)

Species	Site I (Ungraded)		Site II (Graded)	
	Survival	Median height	Survival	Median height
	Percent	Feet	Percent	Feet
Black locust	84	27	96	24
Ash	77	10	83	13
Silver maple	43	8	23	11
Cottonwood	29	19	55	25
Sweetgum	66	17	51	13
Black walnut	27	6	44	10
Black walnut seed	1/ 32	4	1/ 71	8
Osage-orange	33	8	54	8
Yellow-poplar	37	11	8	9
Jack pine	52	11	36	9
Pitch pine	63	12	57	10
Red pine	61	7	8	4
Virginia pine	70	12	27	10
White pine	59	8	2	2
Shortleaf pine	40	11	25	8
Loblolly pine	61	20	21	11
Eastern redcedar	68	9	62	11

1/ Percent of seed spots with one or two live trees.

Table 5.--Ten-year survival and median heights of trees planted on acid, silty clay of Jackson County (District V)

Species	Site I (Acid, silty clay)	
	Survival	Median height
	Percent	Feet
Black locust	38	18
Ash	24	9
Silver maple	21	9
Cottonwood	10	12
Sweetgum	32	12
Black walnut	4	3
Black walnut seed	1/ 7	4
Osage-orange	11	7
Yellow-poplar	7	7
Jack pine	30	10
Pitch pine	27	11
Red pine	11	6
Virginia pine	16	10
White pine	12	9
Shortleaf pine	9	10
Loblolly pine	29	14
Eastern redcedar	8	9

1/ Percent of seed spots with one or two live trees

Table 6.--Ten-year survival and median heights of trees planted on glacial till and silty clay spoil banks of Randolph County (District V)

Species	Site II (Dense vegetation)		Site III (Sparse vegetation)	
	Survival	Median height	Survival	Median height
	Percent	Feet	Percent	Feet
Black locust	31	24	83	28
Ash	71	13	83	10
Silver maple	9	14	23	8
Cottonwood	0	--	1/ --	--
Sweetgum	25	10	70	15
Black walnut	34	11	69	11
Black walnut seed	2/ 30	10	2/ 61	9
Osage-orange	36	12	66	11
Yellow-poplar	0	--	26	7
Jack pine	22	9	45	8
Pitch pine	26	8	64	7
Red pine	7	5	20	5
Virginia pine	29	11	57	10
White pine	2	3	32	5
Shortleaf pine	9	8	30	5
Loblolly pine	30	16	42	12
Eastern redcedar	52	10	60	12

1/ Survival and height measurements were not taken because of the difficulty of separating planted cottonwood from the natural cottonwood.

2/ Percent of seed spots with one or two live trees.

Table 7.--Twelve-year survival and median heights of trees underplanted in black locust and shortleaf pine plantations of Perry County (District V)

Species	Black locust overstory		Shortleaf pine overstory	
	Survival	Median height	Survival	Median height
	Percent	Feet	Percent	Feet
Yellow-poplar	48	30	68	9
Black walnut	73	32	79	13
Black walnut seed	1/ 54	30	1/ 71	10
Silver maple	64	18	63	6
Osage-orange	46	12	67	7
Sweetgum	21	11	87	13
Ash	56	8	84	7
Black locust	--	--	60	31

1/ Percent of seed spots with one or two live trees.

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